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Vahida

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(54) CATENARY FRONT-END GEAR AND METHOD

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(52) **U.S. Cl.**
CPC ***G01V 1/3817*** (2013.01)

(58) **Field of Classification Search**
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USPC 114/242; 367/16
See application file for complete search history.

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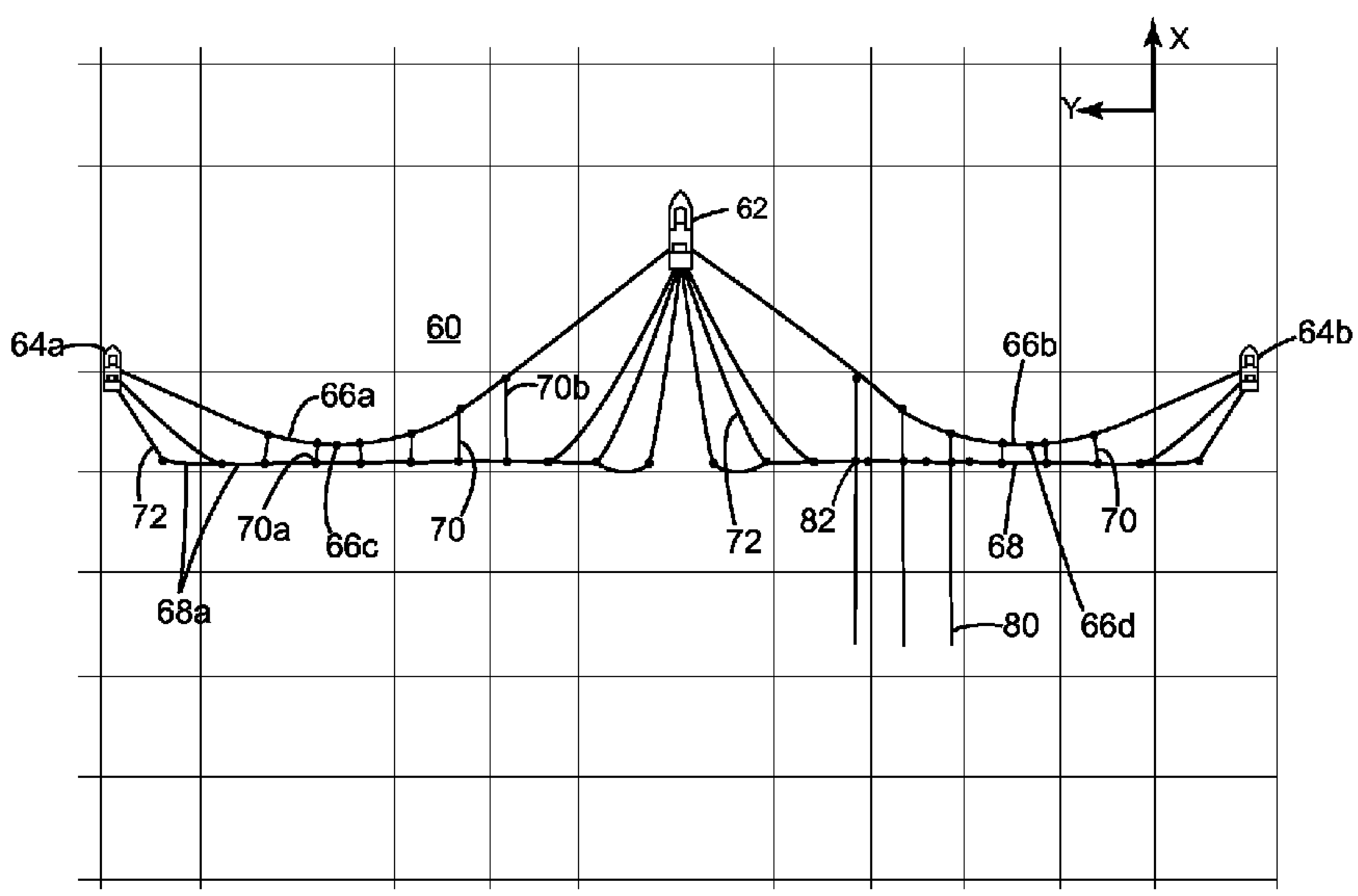
(57) **ABSTRACT**

Method and catenary front-end gear for towing streamers under water. The catenary front-end gear includes a main cable configured to be attached to a vessel and a device; a connecting system configured to connect streamers to the main cable; and plural streamers. The main cable takes a catenary shape when towed by the first vessel underwater.

20 Claims, 13 Drawing Sheets



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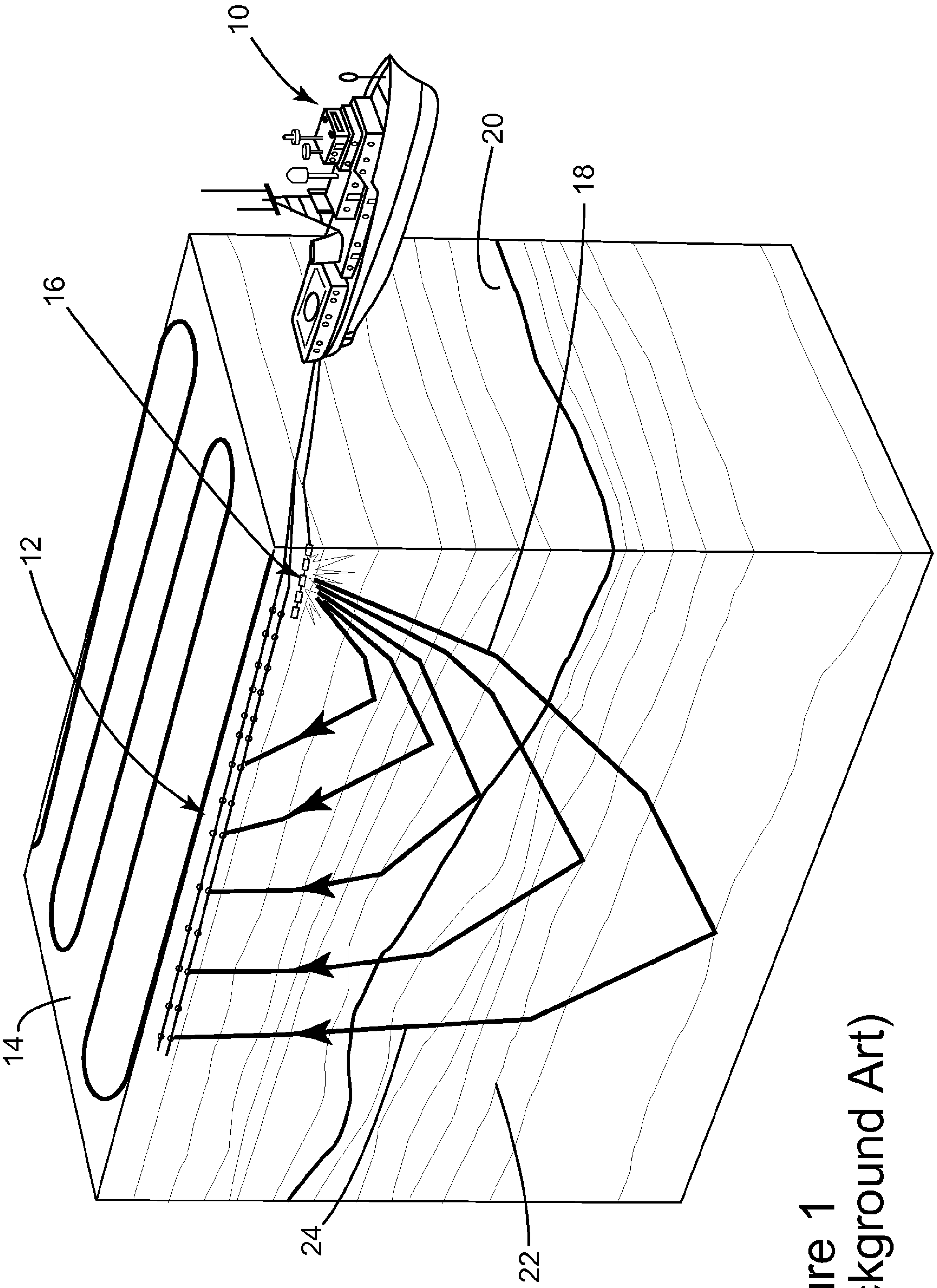
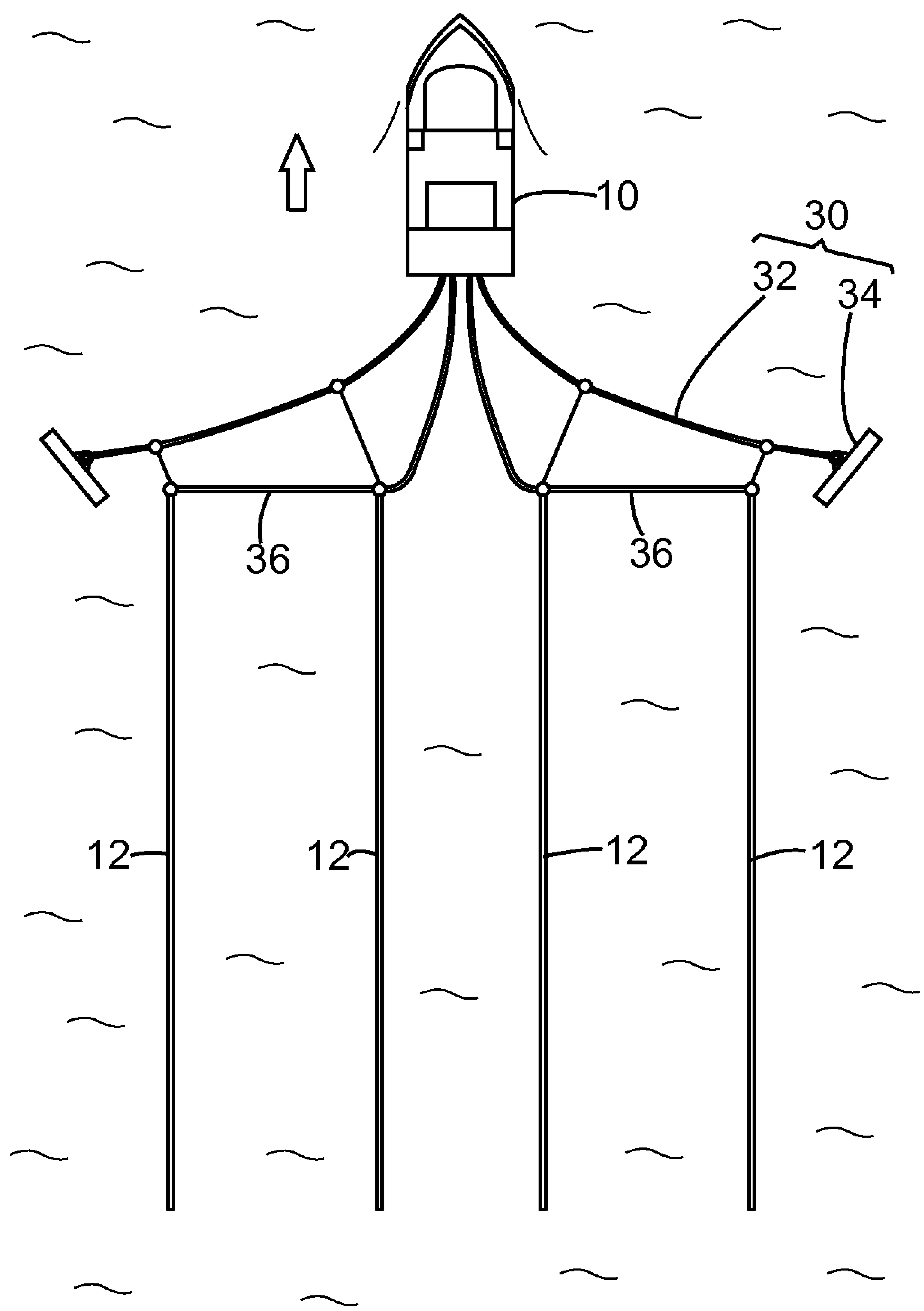


Figure 1
(Background Art)

Figure 2
(Background Art)



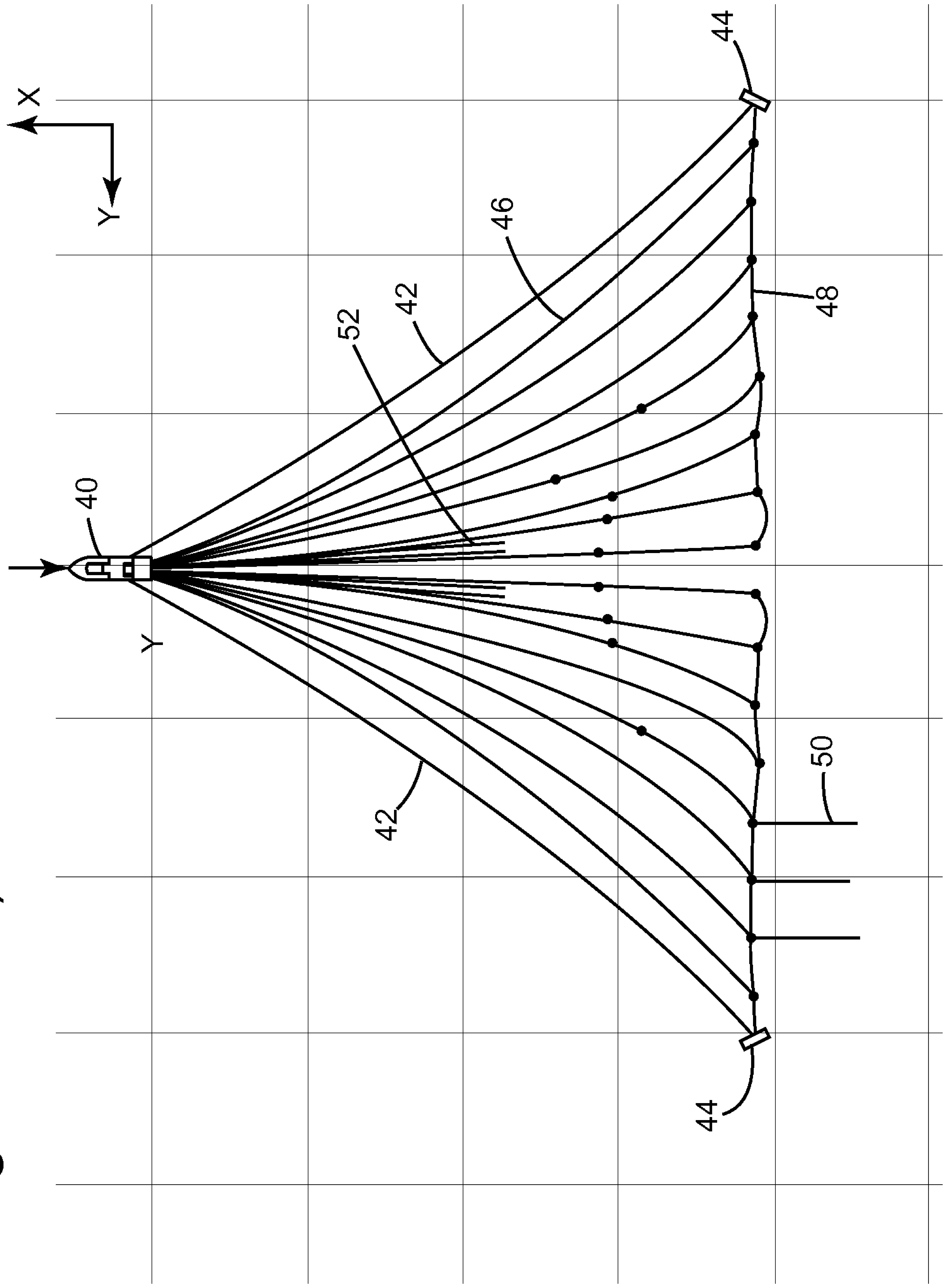


Figure 3
(Background Art)

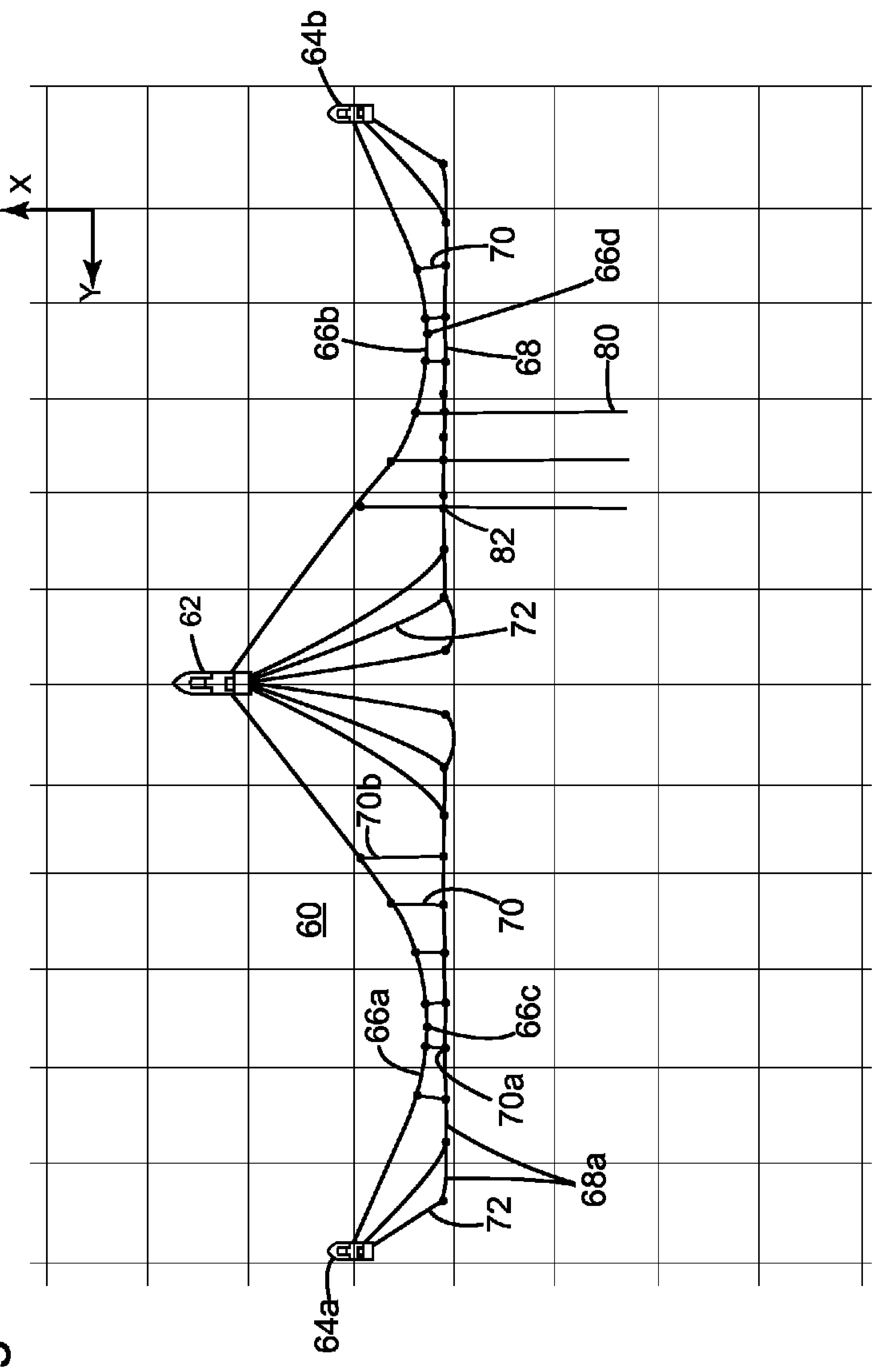


Figure 4

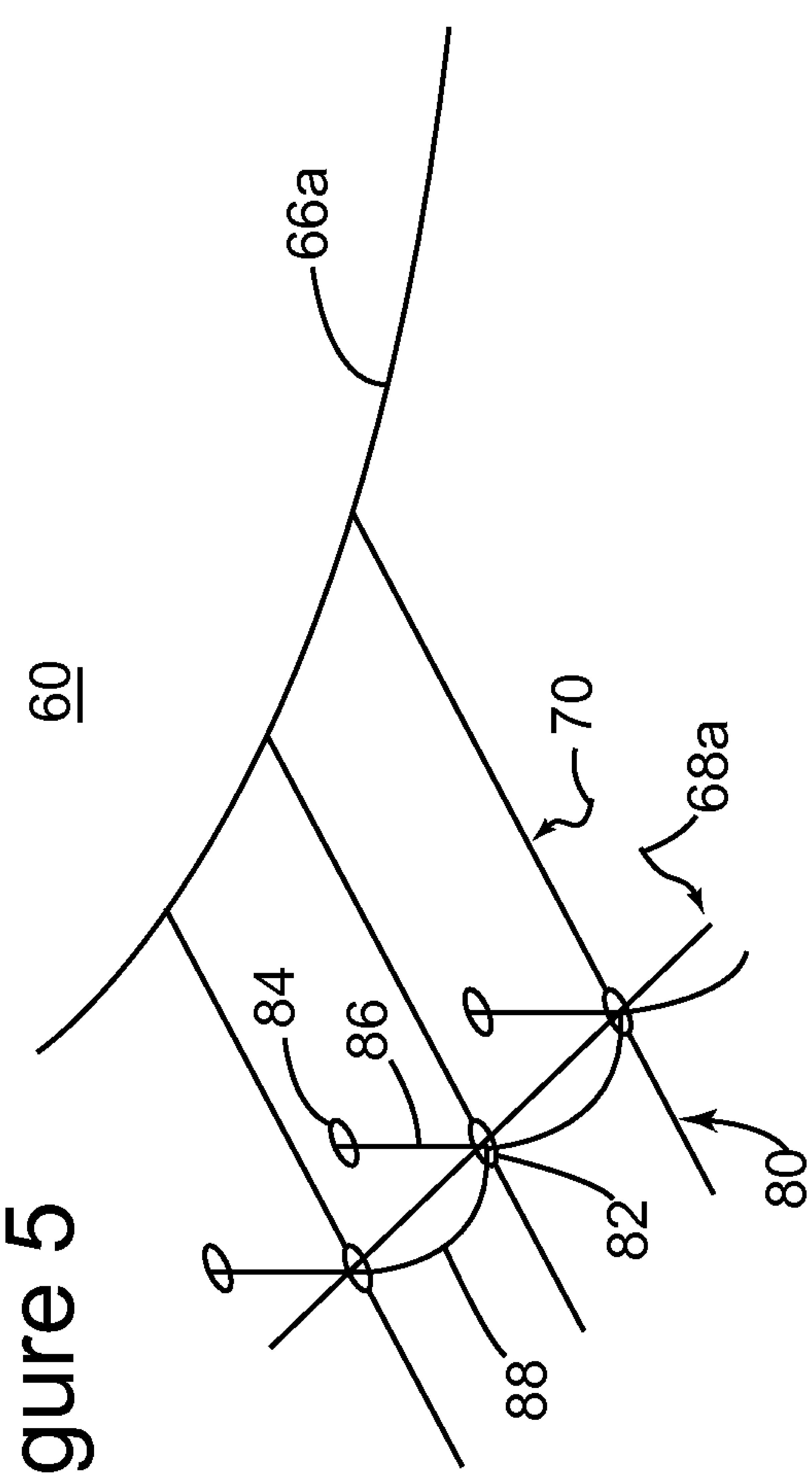


Figure 5

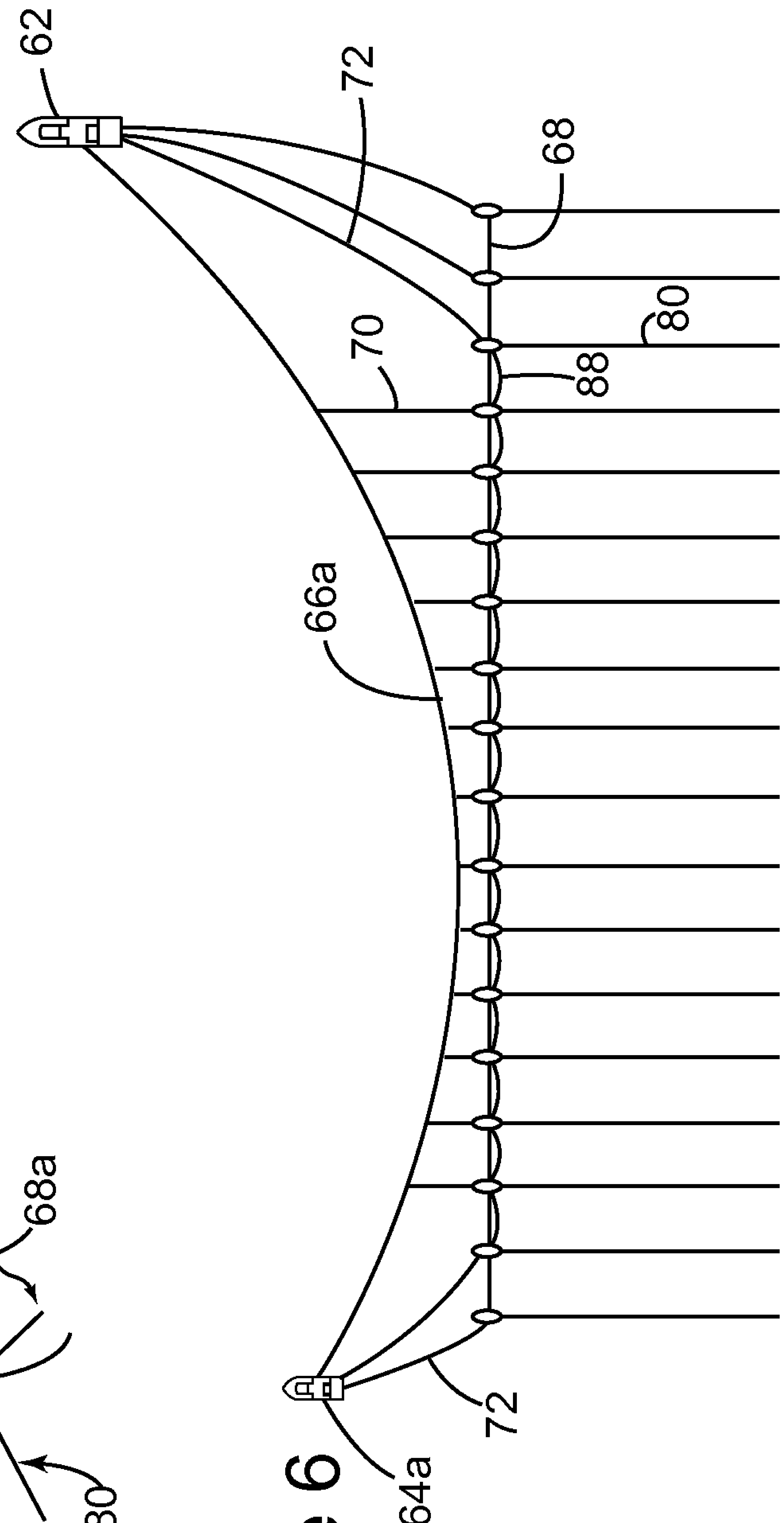


Figure 6

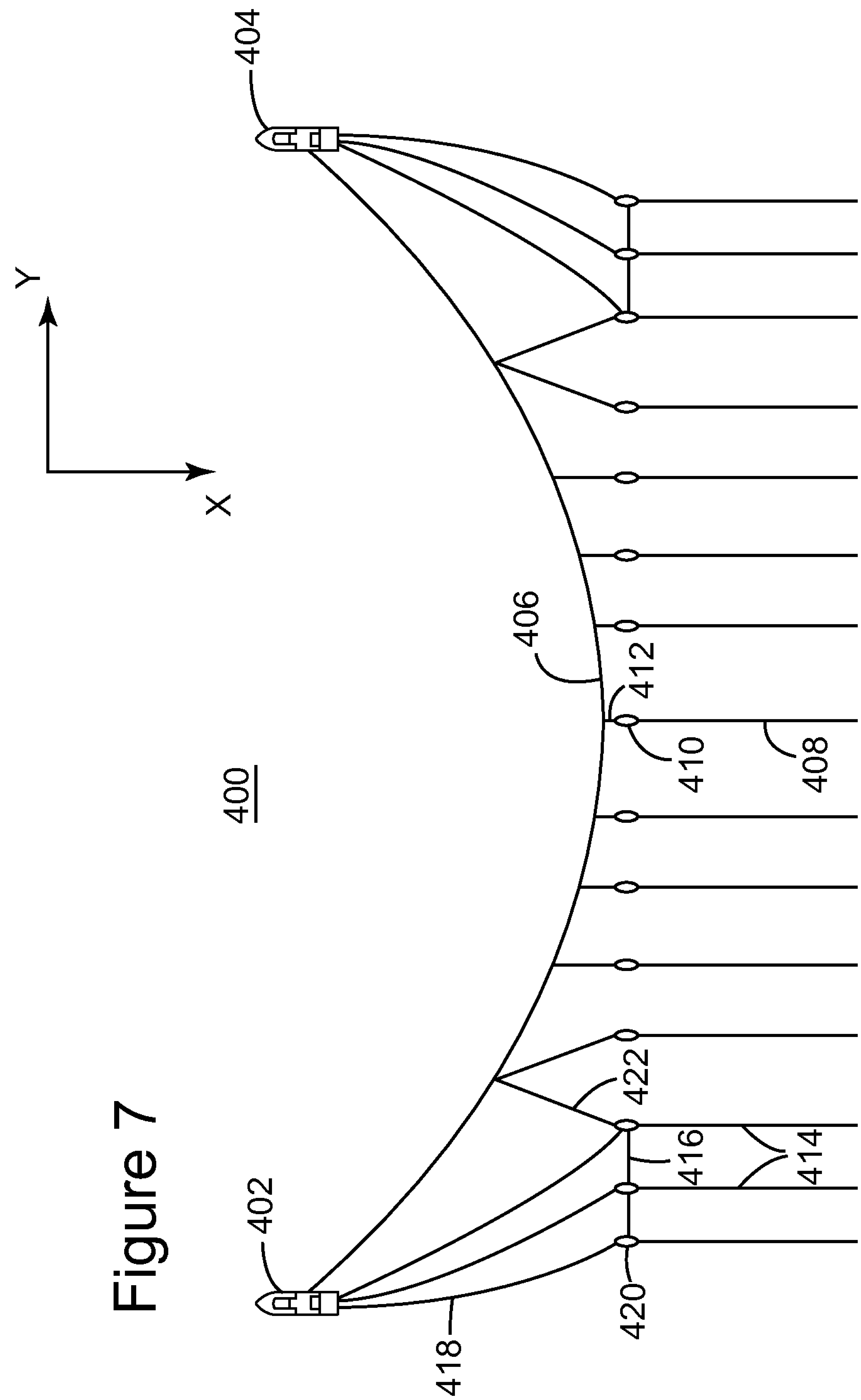


Figure 7

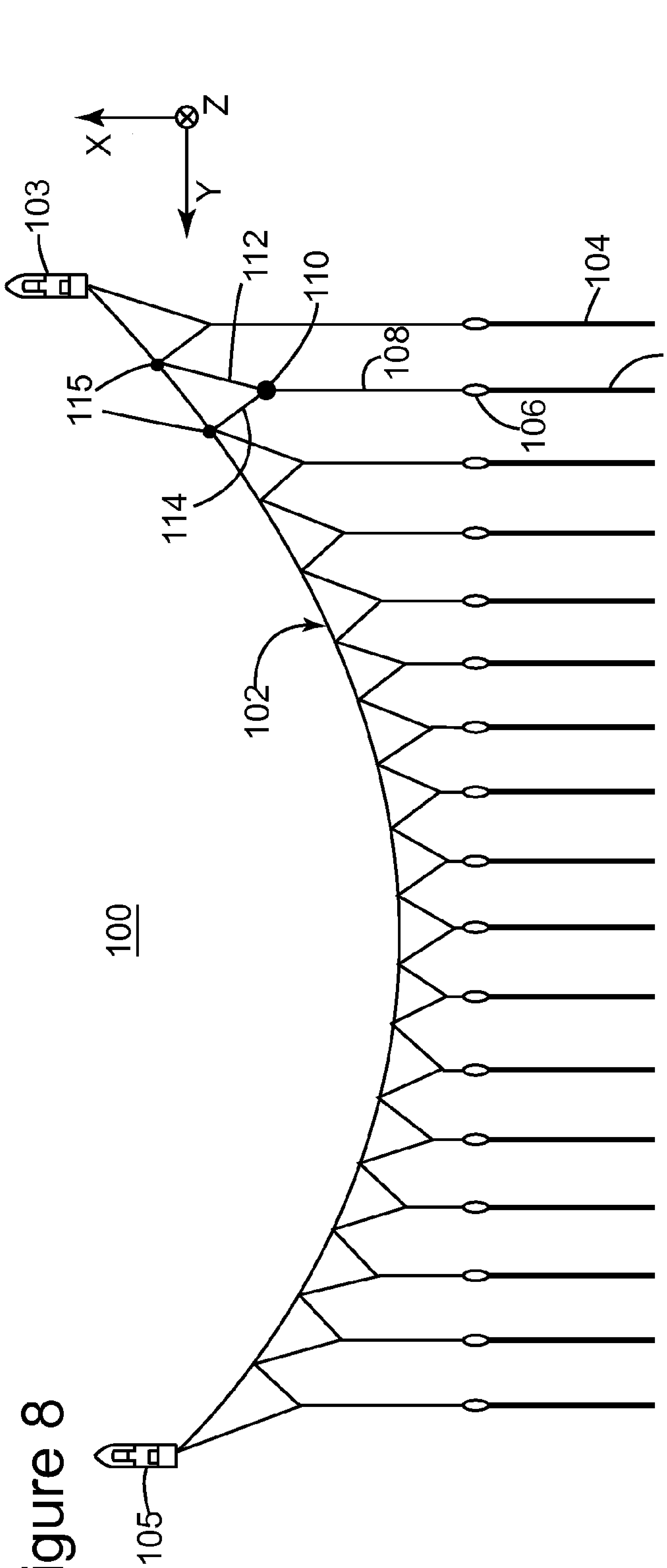


Figure 8

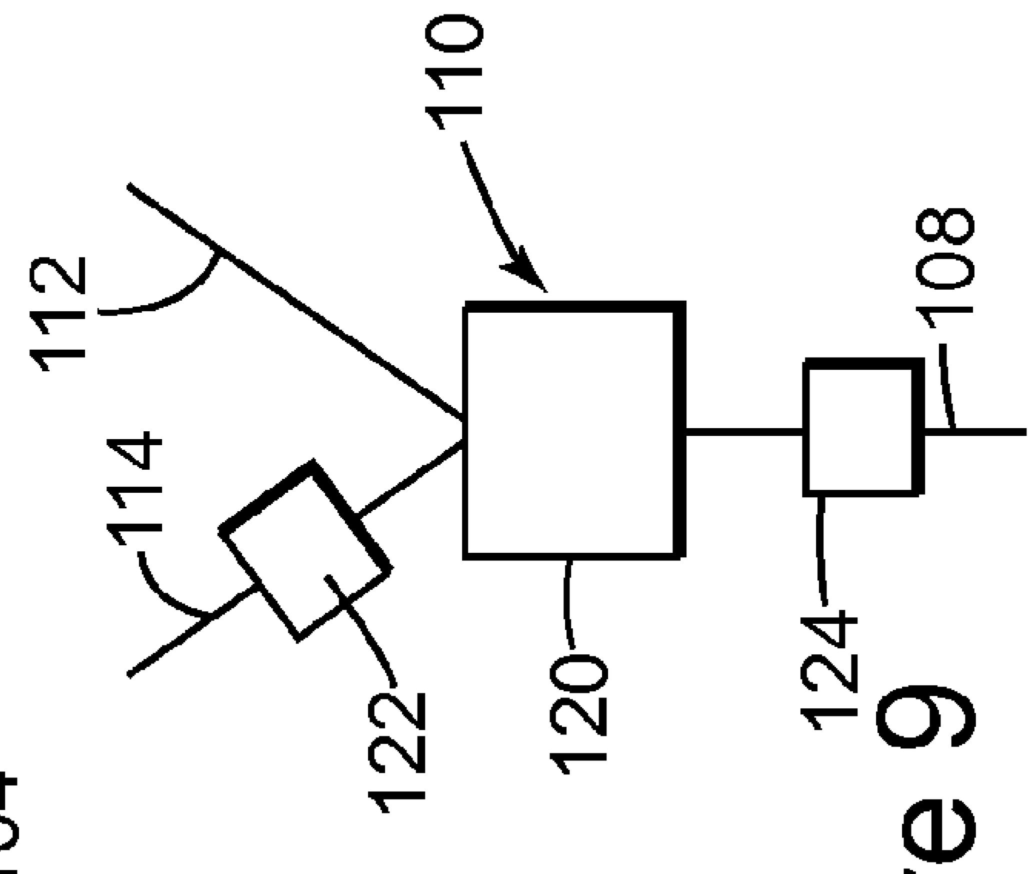


Figure 9

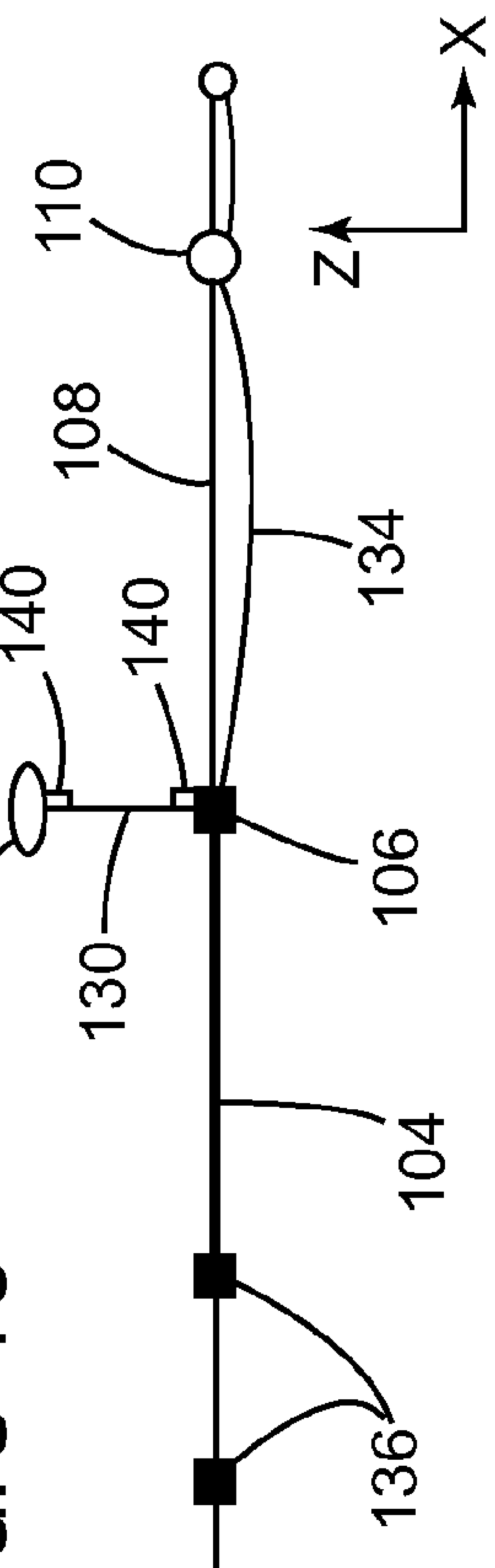


Figure 10

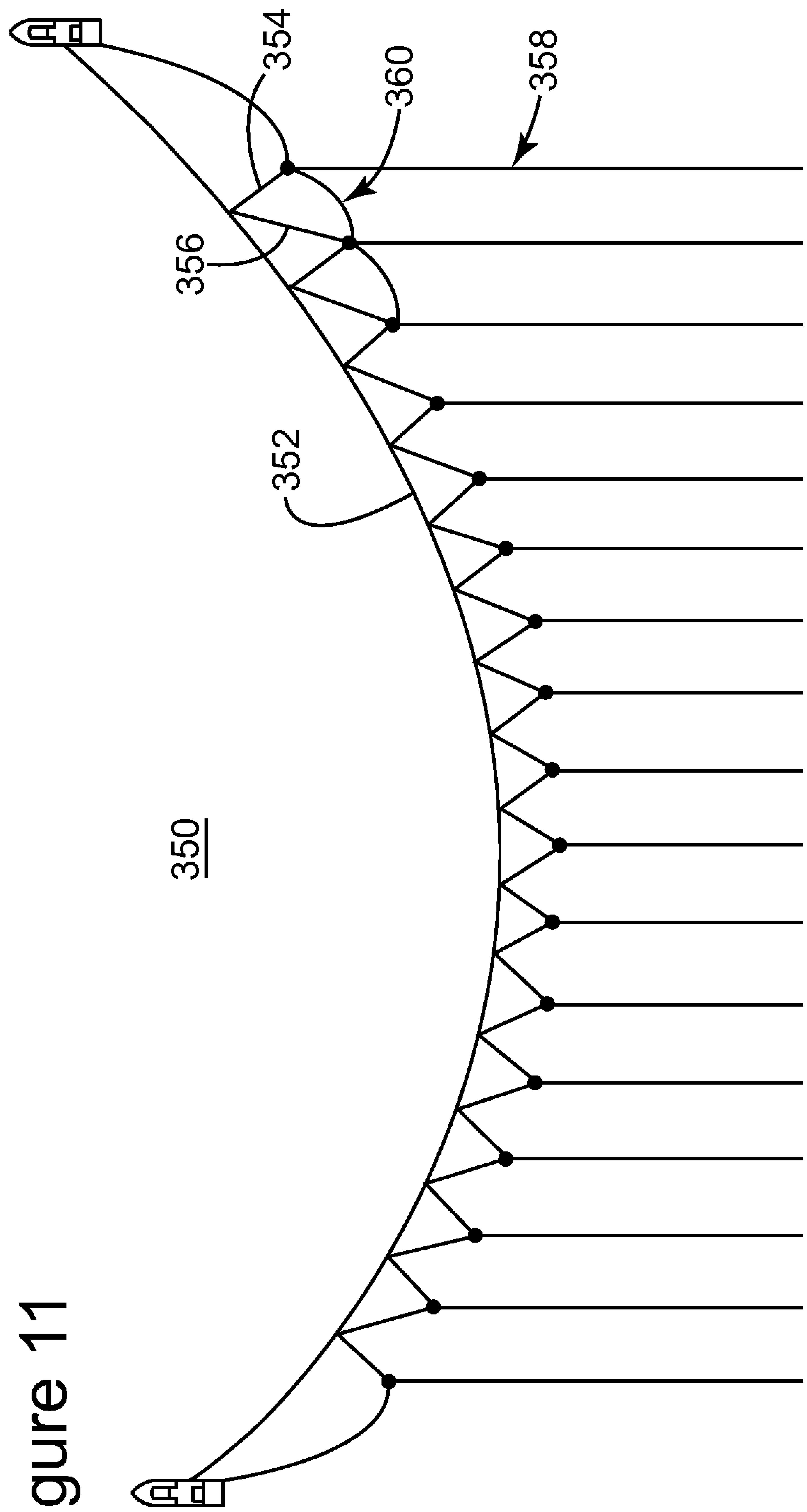


Figure 11

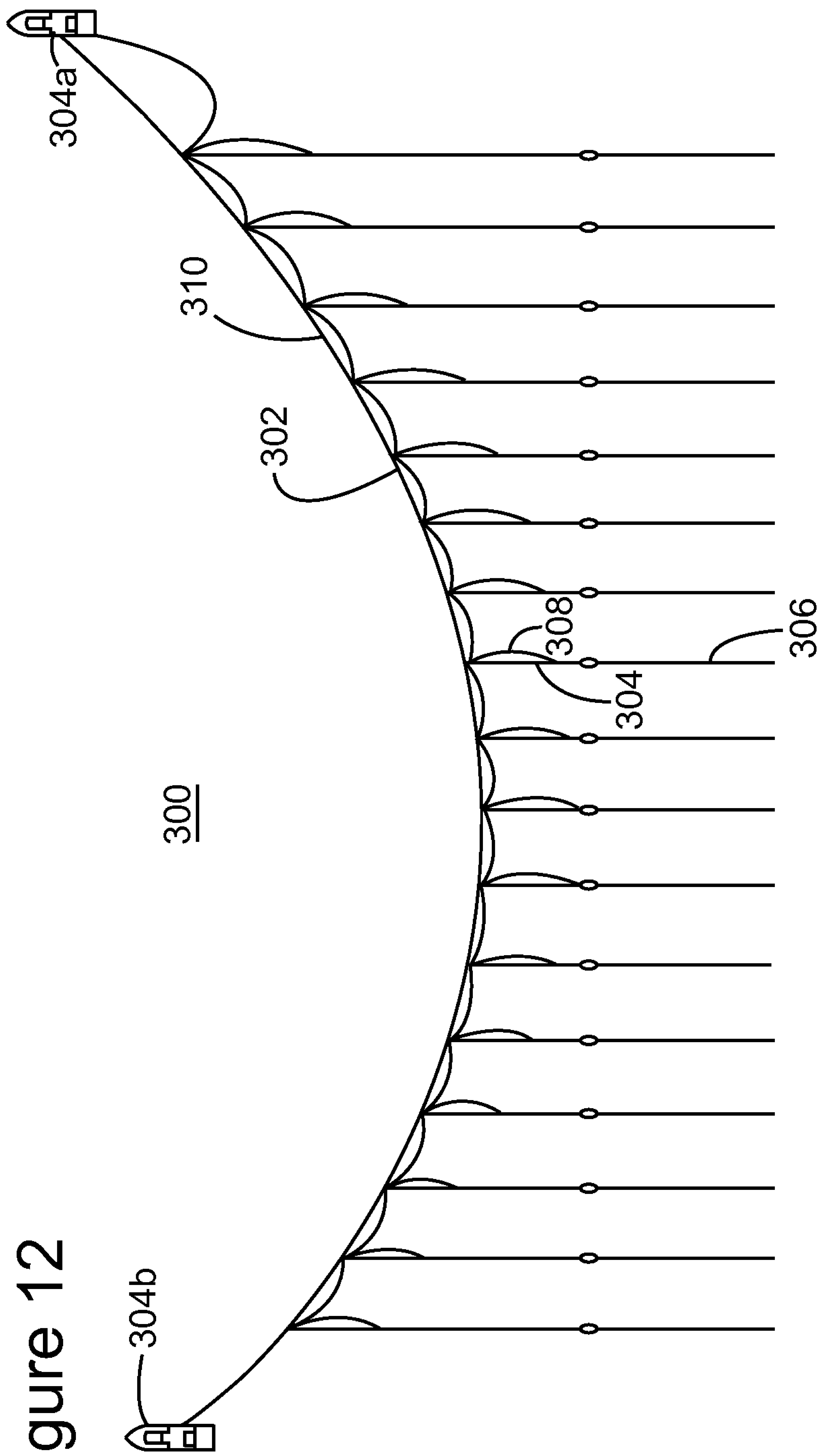


Figure 12

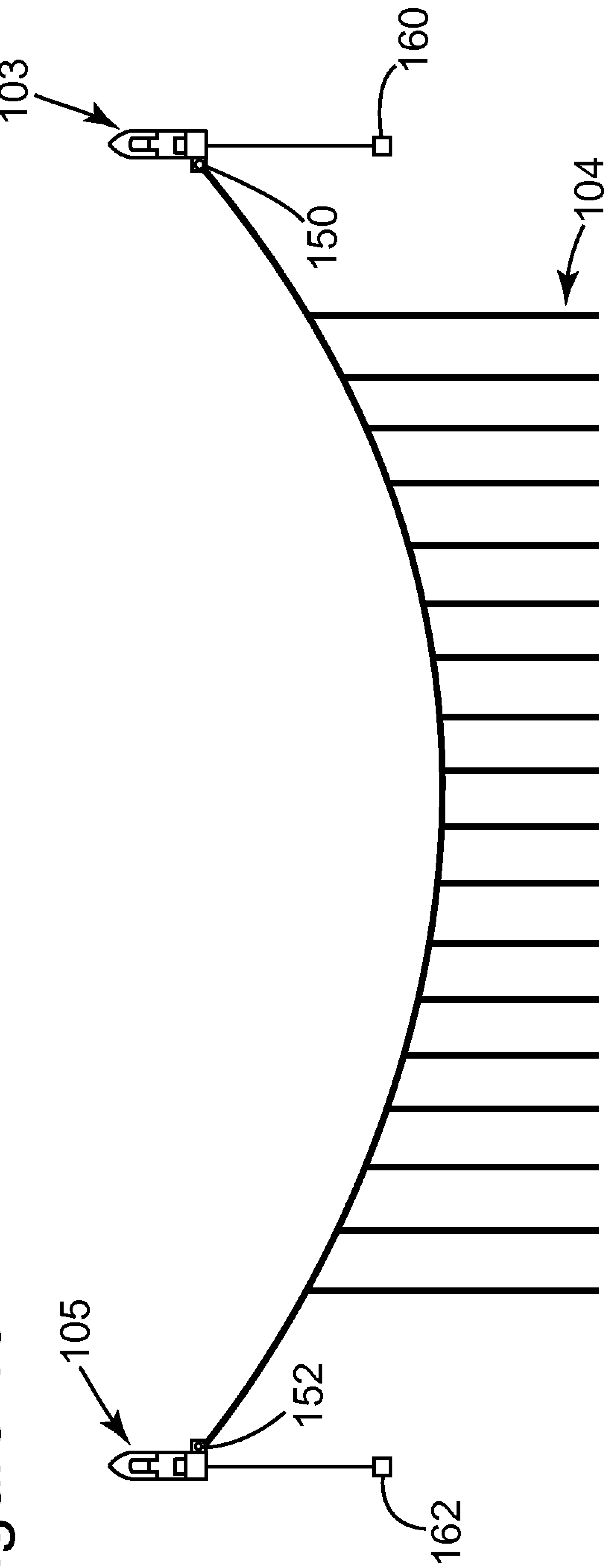


Figure 13

200

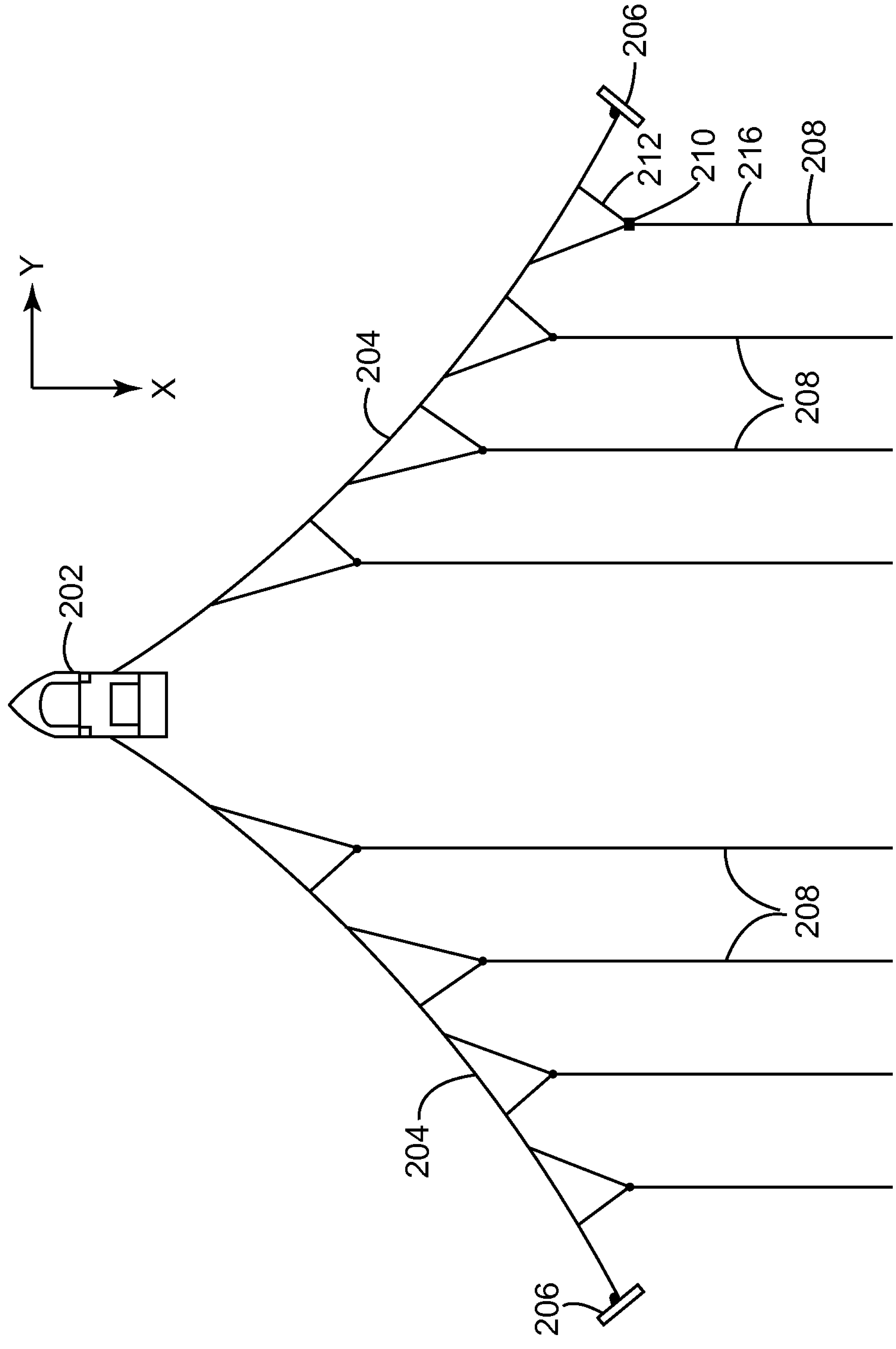


Figure 14

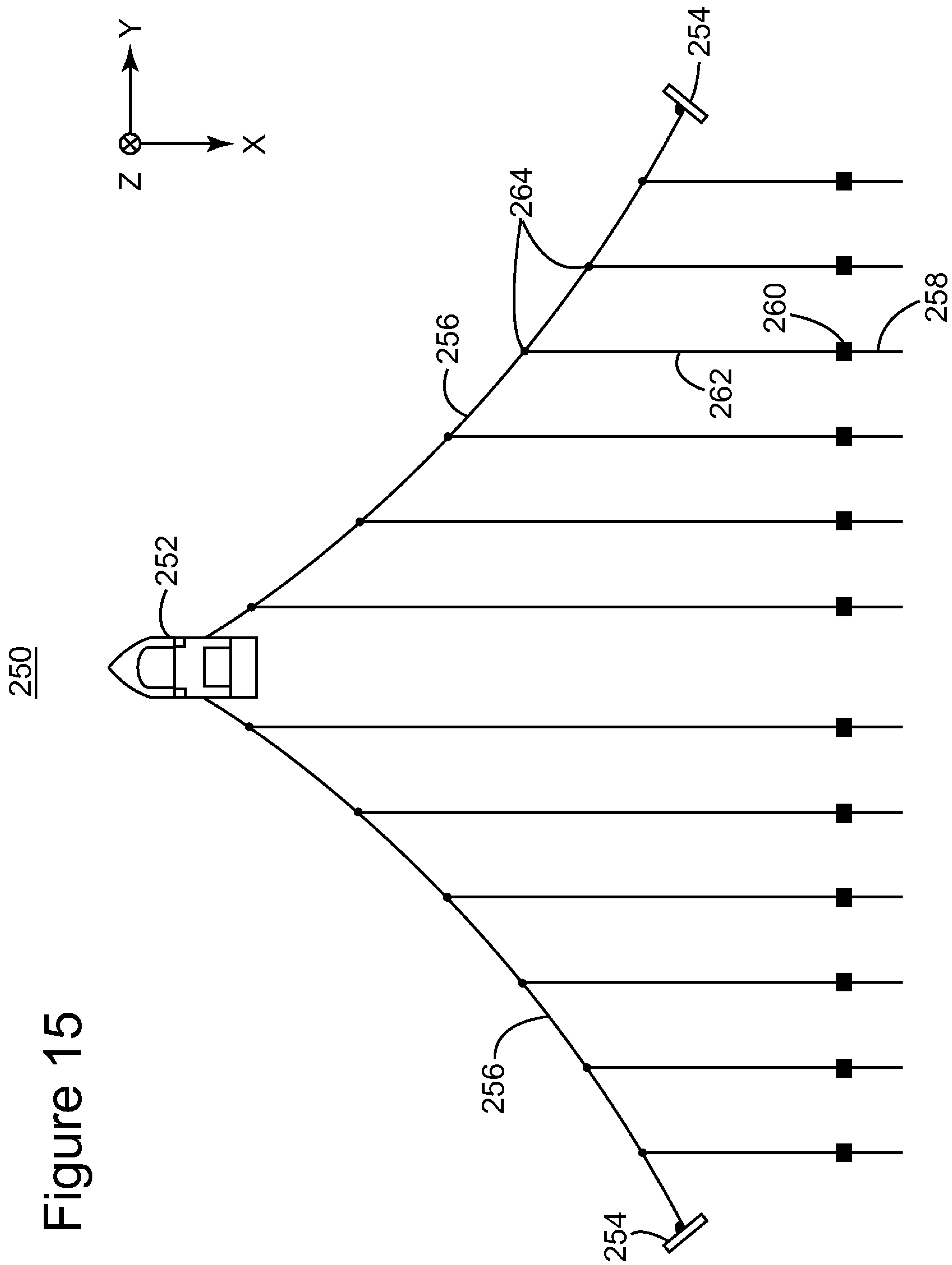
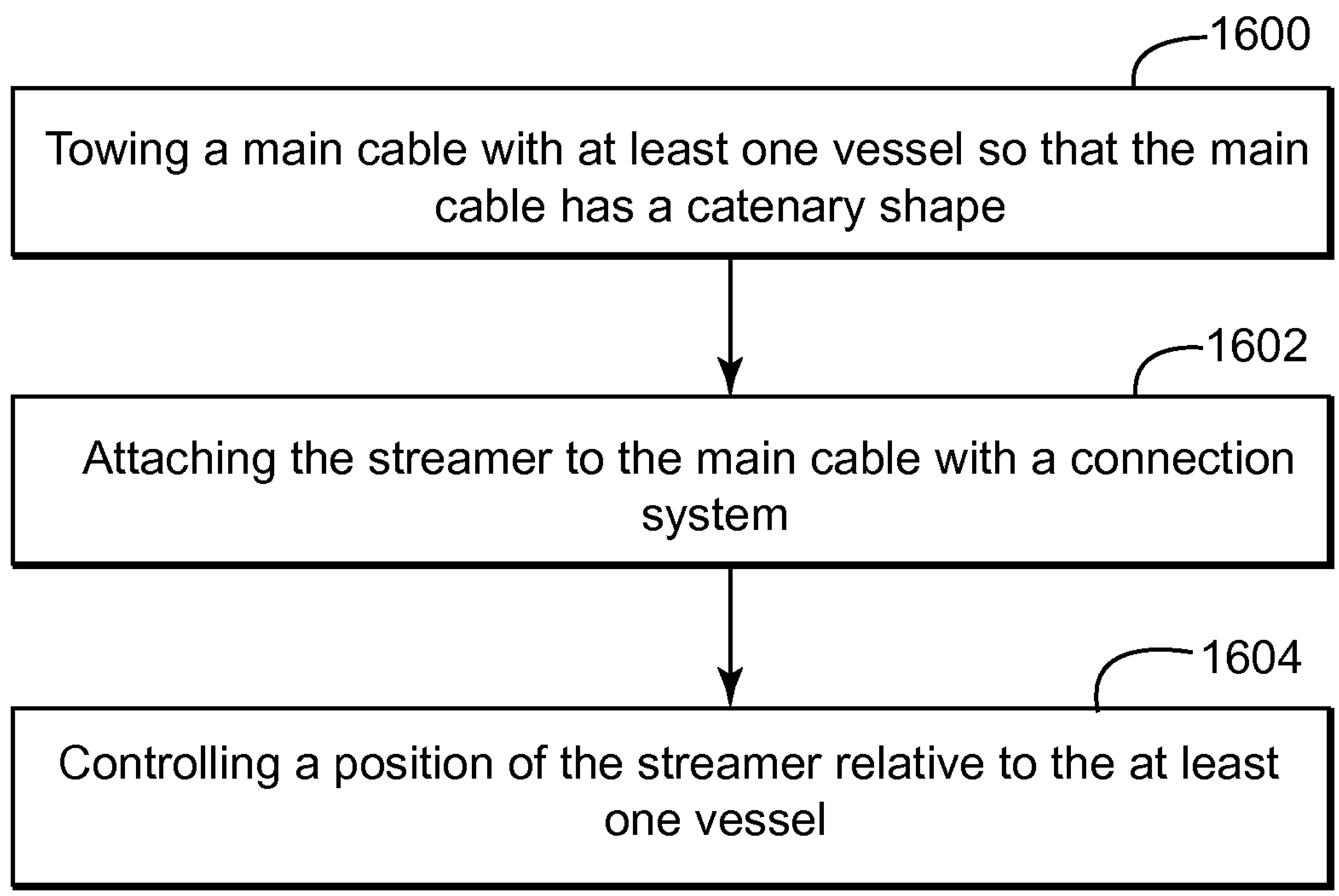


Figure 15

Figure 16


1600
Towing a main cable with at least one vessel so that the main cable has a catenary shape
1602
Attaching the streamer to the main cable with a connection system
1604
Controlling a position of the streamer relative to the at least one vessel

CATENARY FRONT-END GEAR AND METHOD

BACKGROUND

1. Technical Field

Embodiments of the subject matter disclosed herein generally relate to methods and systems and, more particularly, to mechanisms and techniques for towing seismic equipment under water.

2. Discussion of the Background

During the past years, the interest in developing new oil and gas production fields has dramatically increased. However, the availability of land-based production fields is limited. Thus, the industry has now extended drilling to offshore locations, which appear to hold a vast amount of fossil fuel. Offshore drilling is an expensive process. Thus, those engaged in such a costly undertaking invest substantially in geophysical surveys in order to more accurately decide where to drill in order to avoid a dry well.

Marine seismic data acquisition and processing generate a profile (image) of the geophysical structure (subsurface) under the seafloor. While this profile does not provide an accurate location for the oil and gas, it suggests, to those trained in the field, the presence or absence of oil and/or gas. Thus, providing a high resolution image of the subsurface is an ongoing process for the exploration of natural resources, including, among others, oil and/or gas.

During a seismic gathering process, as shown in FIG. **1**, a vessel **10** drags an array of seismic detectors provided on streamers **12**. The streamers may be disposed horizontally, i.e., lying at a constant depth relative to a surface **14** of the ocean. The vessel **10** also tows a seismic source assembly **16** that is configured to generate an acoustic wave **18**. The acoustic wave **18** propagates downwards toward the seafloor **20** and penetrates the seafloor until eventually a reflecting structure **22** (reflector) reflects the acoustic wave. The reflected acoustic wave **24** propagates upwardly until the same is detected by detector **26**.

The streamers **12** are shown in FIG. **2** spreading over a predetermined area. This is called the seismic spread. In order to maintain the plural streamers **12** substantially parallel and at equal distance from each other, various front-end gears are used. Streamers **12** are spread out to a desired width to provide measurements of the geological conditions over an acquisition area.

An example of a front-end gear **30** is shown in FIG. **2**. The front-end gear **30** is provided between the vessel **10** and the various streamers **12** and this gear is configured to achieve the desired positioning for the streamer heads. FIG. **2** shows the front-end gear **30** to include cables **32** connected between the vessel **10** and deflectors **34**. Deflector **34** is a structure capable of generating the necessary lift when towed to keep the streamers deployed in the transverse direction with respect to the sailing line of the towing vessel **10**. Spacers **36** are attached to the cables **32** for distributing the lift force among them in order to obtain a substantially linear profile for the position of the streamer heads.

As said above, to spread the streamers transversely in relation to the seismic vessel, the deflectors **34** are usually used. Such deflectors are traditionally passive devices including one or more wings providing a lift in the required direction. Because of the towing resistance in the water, caused both by the deflector and the towed cables, there are, however, limits to the lift which may be obtained using passive deflectors. Thus, due to the limited lift that can be generated by the deflectors, a width of the seismic spread is also limited, which

is undesirable. When the deflector is used in seismic surveys it will in addition be loaded with the streamers to be pulled sideways. Thus, there is a limit to the width of the cable tow with passive deflectors.

Another conventional configuration that is presently in use is shown in FIG. **3**. FIG. **3** shows a vessel **40** towing two ropes **42** provided at respective ends with deflectors **44**. Plural lead-in cables **46** are connected to streamers **50** (e.g., they may form a single cable). The plural lead-in cables **46** also connect to the vessel **40**. The streamers **50** are maintained at desired separations from each other by separation ropes **48**. Plural sources **52** are also connected to the vessel **40**. However, this configuration introduces a large drag. Although the positioning of the streamers may be good, this configuration introduces high internal forces and high resulting stresses in the lines (cables/ropes) and connection means. This results from the raying pattern and the highly constrained geometry where everything is connected by tensioned lines.

Further, the processing techniques for seismic data require longer and more streamers, which only increase the load (due to their drag) of the surveying vessel that tows the streamers. However, as the towing vessel has a limited power availability, the large drag needs to be reduced. Accordingly, it would be desirable to provide systems and methods that provide the operator of the vessel with the capability to use long streamers and an increased number of streamers if so desired.

As the use of the seismic vessel is expensive, it is advantageous to make the width of the spread as large as possible, with a large number of streamers, so that one vessel pass covers an area as large as possible. In this regard, ultra-wide-tow seismic spread using more than 20 streamers is targeted but is something unfeasible using conventional front-end gear architectures. An illustrative configuration in this case could be one with 30 streamers, each having a length of up to 8000 m and a separation between the streamers in the order of 100 m. A short hand for such configuration is 30×8000×100.

On the other hand, for doing dense acquisition, smaller separation between streamer heads is required, for example in the range of 25 to 50 meters. This configuration is difficult to achieve using conventional front-end gears. An exemplary application for this type of acquisition is the configuration composed of 20 streamers, each streamer being 6000 m long and having a separation between streamers of 25 m, i.e., 20×6000×25.

For very wide and low density acquisitions a very large separation is to be used for streamers, in the order of 200 to 300 meters. Here too there are difficulties when using the conventional front-end gears. A typical application in this case would be one with 10 streamers, each streamer being 10000 m long and the separation between the streamers is in the range of 300 m, i.e., 10×10000×300.

SUMMARY

According to an exemplary embodiment, there is a catenary front-end gear for towing streamers under water. The catenary front-end gear includes a main cable configured to span between a first vessel and a device; a connecting system configured to connect plural streamers to the main cable; and the plural streamers. The main cable takes a substantially catenary shape when towed by the first vessel underwater.

According to another exemplary embodiment, there is a method for adjusting a position of a streamer when towed under water. The method includes a step of towing a main cable with at least one vessel so that the main cable has a catenary shape; a step of attaching the streamer to the main

cable with a connection and control system; and a step of controlling a position of the streamer relative to the at least one vessel.

According to yet another exemplary embodiment, there is a hybrid front-end gear for towing plural streamers underwater along an X axis. The hybrid front-end gear includes a first cable configured to connect to a first vessel and a second vessel; transversal ropes configured to extend along an Y axis that is substantially perpendicular to the X axis; and links configured to connect the transversal cable to the first cable. The first cable takes a catenary shape when towed underwater and the transversal ropes are substantially straight and is the plural ropes are configured to connect to the plurality of streamers.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate one or more embodiments and, together with the description, explain these embodiments. In the drawings:

FIG. **1** is a schematic diagram of a conventional marine seismic acquisition configuration;

FIG. **2** is a schematic diagram of another conventional marine seismic acquisition configuration;

FIG. **3** is a schematic diagram of still another conventional marine seismic acquisition configuration;

FIG. **4** is a schematic diagram of a marine seismic acquisition system having catenary cables according to an exemplary embodiment;

FIG. **5** is a detailed view of a part of a catenary cable according to an exemplary embodiment;

FIG. **6** is a top view of a seismic data acquisition system having a catenary cable according to an exemplary embodiment;

FIG. **7** is a top view of another seismic data acquisition system according to an exemplary embodiment

FIG. **8** is a top view of a seismic data acquisition system having a catenary cable according to an exemplary embodiment;

FIG. **9** is a schematic diagram of a connection between various cables of a seismic data acquisition system according to an exemplary embodiment;

FIG. **10** is a side view of a streamer and a lead-in cable of a seismic data acquisition system according to an exemplary embodiment;

FIG. **11** is a top view of still another seismic data acquisition system according to an exemplary embodiment;

FIG. **12** is a top view of another seismic data acquisition system according to an exemplary embodiment;

FIG. **13** is a top view of a seismic data acquisition system having a catenary cable for streamers and a seismic source according to an exemplary embodiment;

FIG. **14** is a top view of a seismic data acquisition system that uses deflectors according to an exemplary embodiment;

FIG. **15** is a top view of a seismic data acquisition system that uses birds for positioning the streamers according to an exemplary embodiment; and

FIG. **16** is a flow chart illustrating a method for controlling streamers of a seismic data acquisition system according to an exemplary embodiment;

DETAILED DESCRIPTION

The following description of the exemplary embodiments refers to the accompanying drawings. The same reference numbers in different drawings identify the same or similar elements. The following detailed description does not limit the invention. Instead, the scope of the invention is defined by the appended claims. The following embodiments are discussed, for simplicity, with regard to the terminology and structure of a front-end gear for towing plural streamers. However, the embodiments to be discussed next are not limited to these structures, but may be applied to other structures that are capable to tow seismic sources or other seismic related equipment.

Reference throughout the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with an embodiment is included in at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrases "in one embodiment" or "in an embodiment" in various places throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments.

According to an exemplary embodiment illustrated in FIG. **4**, there is a hybrid front-end gear **60** that is attached to a master vessel **62** and two slave vessels **64***a-b*. At least one of the vessels is a seismic vessel transporting multiple streamers on board. The second vessel can be either a tug boat or a seismic vessel in cases where a big number of streamers are to be deployed at sea.

A first cable **66***a* (called catenary tow line) is provided between the master vessel **62** and slave vessel **64***a* and a second cable **66***b* (catenary tow line) is provided between the master vessel **62** and slave vessel **64***b*. In the following, a cable is considered an element capable of transferring data and/or electrical power and also capable of sustaining a given load, i.e., having a structural role in transferring loads. A rope or link is considered to be an element that transfers a load but not capable of transmitting data and/or electrical power. In one application, the hybrid front-end gear **60** includes only a slave vessel **64***a* and the first cable **66***a*, as will be discussed later with regard to FIG. **6**.

One or more transversal ropes **68** are connected from the first cable **66***a* and from the second cable **66***b* via links **70**. Links **70**, which may be ropes or cables or both or other means known in the art, have different lengths depending on their location on the Y axis. For example, link **70** may include a cable part and also a rope part, where the rope part is used to adjust a position of the corresponding streamer and the cable part is configured to transmit data and/or power. Links **70** may be configured to form a single unit with streamers **80**. For the embodiment shown in FIG. **4**, the first cable **66***a* has a point **66***c* that is furthest on the X axis from vessel **62** and the second cable **66***b* has a similar point **66***d*. Links **70***a* are shortest next to these points **66***b* and **66***c*, e.g., 35 m. However, there are links **70***b* that are much longer, for example, around 160 m as also shown in FIG. **4**. Direct links **72** between the vessels and the transversal ropes **68** are also provided. These links **72** may have lengths between, for example, 200 and 400 m depending on their location on the Y axis.

It is noted that the ends of both the first and second cables **66***a* and **66***b* are fixed only to the master vessel and the corresponding slave vessel. Thus, these cables take a substantially catenary shape. It is noted that due to various elements (load, friction, connections, etc.), a cable or rope will not take a catenary shape but a shape that approximates the catenary shape, i.e., substantially catenary shape. A catenary shape is considered a curve that an idealized hanging chain or cable assumes when supported at its ends and acted on only by its own weight. In the present case, the drag on each section of the first and second cables acts as the weight. If ropes **68** would be connected only from the cables **66***a* and **66***b*, such a gear would be called a catenary gear. The presence of the direct links **72** connecting parts of the ropes **68** to the vessels determine the gear **60** to be called "hybrid."

As the first cable **66***a* and the second cable **66***b* may have a length of about 1300 m, a total span of the transversal ropes **68** may be about 2100 m. These numbers are illustrative and not intended to limit the exemplary embodiments. For the above noted numbers, an offset between the vessel **62** and the transversal ropes **68** may be around 380 m and an offset between the vessel **64***a* and the transversal ropes **68** may be around 170 m. Noting that these numbers are illustrative and not intended to limit the exemplary embodiments, it is observed that such small offsets are not the norm in the industry and the span of the transversal ropes **68** is significant. The transversal ropes **68** are connected between streamers **80** at connections **82**. The transversal ropes **68** may be made of a single cable or of multiple cables connected to each other. For example, ropes **68***a* may be provided between adjacent links **70** or **72**.

The configuration shown in FIG. **4** may support, for example, 22 streamers **80**, each streamer 8,000 m long and a distance between two adjacent streamers may be around 100 m. For this configuration, a drag on the master vessel is about 50 tons and a drag on each of the slave vessel is about 14 tons. However, the system shown in FIG. **4** does not allow a transversal control of an individual streamer as a change in the length of a separation rope **68** will impact the positions of all the streamers as the streamers are interconnected. Also, the numbers discussed in this paragraph are for illustration and more or less streamers **80** may be attached.

Still with regard to FIG. **4**, the seismic source(s) can either be towed by the vessels towing the streamer system, or by independent source vessels positioned around the seismic spread. The connections between links **70** and cables **66***a* and **66***b* are purely structural in the embodiment described above, as the links **70** have a structural role of transmitting towing forces from the cable **66***a* to the streamer heads. Standard structural rope connectors available in the offshore industry and having quick connect/disconnect capability can be used to connect the links **70** to cables **66***a* and **66***b*. This last feature eases the deployment and recovery of the seismic spread devised according to the current invention.

The hybrid front-end gear **60** need not only to provide the mechanical strength for towing the streamers but also to provide electrical and/or data transmission capabilities. In this regard, it is noted that each receiver on the streamers may need electrical power and also may need to exchange data with the vessel. Thus, electrical and data cables are connecting the vessel to the receivers of the streamers. These electrical and data cables may be built together with the cables of the front-end gear, e.g., the electrical and data cables may be provided inside the cables of the front-end gear. Alternatively, the electrical and data cables may mirror the cables of the hybrid front-end gear and may be attached on an outside of these cables.

For example, FIG. **5** shows an overall view of the hybrid front-end gear **60** and streamers **80**. The streamers **80** have a connection **82** to the links **70** and each connection **82** may be linked to a corresponding buoy **84** by a rope **86**. Additional buoys may be added at the other end of the streamers and also at various other points along the streamers for maintaining the streamers at a desired depth or depths under water. The streamers **80** are extending under water, at a certain depth that is determined by the length of ropes **86**. Actuators, e.g., winches (not shown), may be provided to the buoys **84** or connections **82** for adjusting as desired the length of the ropes **86**, which in turn adjust the depth of the streamers. Connections **82** may be any of those known in the art and the connections may be configured to be remotely detached from either the streamers or from the links **70**. The electrical and data cables **88** may run from connection to connection along cables **68**, **66***a*, **66***b* and links **70**. In one application, electrical and data cables **88** may be replaced by wireless technology and local power sources for the detectors of the streamers.

FIG. **6** illustrates an exemplary embodiment in which the electrical and data cables **88** run along ropes **68** but not along the first cable **66***a*. Other arrangements of the cables and links are possible as would be appreciated by those skilled in the art. FIG. **6** also illustrates that only a slave vessel **64***a* is used and the first cable **66***a* takes a substantially catenary shape when towed by the vessels **62** and **64***a* and the transversal ropes **68** takes a substantially straight line shape when towed. According to this exemplary embodiment, the second cable **66***b* is not present.

According to an exemplary embodiment, an arrangement is shown in FIG. **7** that includes individual streamers without spread ropes, i.e., individual streamers that may be controlled independently of adjacent streamers. In this respect, the arrangement **400** shown in FIG. **7** has streamers that are not connected to other streamers so that positions of the individual streamers can be controlled independent of the neighboring streamers. FIG. **7** shows two vessels **402** and **404** towing a catenary cable **406**. Part of the streamers **408** are attached by a control mechanism **410** to a lead-in cable **412**. The control mechanism **410** may be a mechanism **110** disclosed in FIG. **9**, a bird **260** disclosed in FIG. **15** or other known mechanism. Because no ropes are provided between these mechanism, a position adjustment on the Y axis of one streamer does not affect other streamers. However, some streamers **414** may be connected to each other by spread ropes **416**. In order for the streamers close to the vessels to stay deployed, lead-in cables **418** may be used to connect the streamers **414** to the corresponding vessel **402** or **404**. Ropes **422** may be used to deploy the streamers **414**. This arrangement is a hybrid front-end gear as positions of the streamers **414** are controlled via the lead-in cables **418** while the positions of the streamers **408** are controlled via mechanism **410**.

According to another exemplary embodiment illustrated in FIG. **8**, a catenary front-end gear **100** has a catenary tow cable (main cable) **102** connected between a master vessel **103** and a slave vessel **105**. Plural streamers **104** are connected by a connecting system to the main cable **102** as discussed next. Each streamer **104** is connected via a connection **106** to a corresponding first link **108**. Each first link **108** may be connected to a control mechanism **110**. The control mechanism **110** is connected by a lead-in cable **112** to the main cable **102** and by a second link **114** also to the main cable **102**. Thus, most if not all of the first links **108** are connected by two means (**112** and **114**) to the main cable **102**. The connections **115** between the lead-in **112** and the second link **114** to the main cable **102** are those known in the art. In one application, the link **114** from a first streamer connects to the main cable **102** at the same point as a lead-in cable **112** of an adjacent streamer. However, in another application, the two elements may connect at different points to the main cable. In another application, the main cable, the first link and the lead-in are cables (i.e., able to transmit data and/or power and to transfer a load) and the second link **114** is a rope, e.g., a synthetic rope without data and/or power transmission capabilities. Elements **108**, **110**, **112**, and **114** may form the connecting system. The reason for these novel connections is discussed next.

According to an exemplary embodiment illustrated in FIG. **9**, the control mechanism **110** has a body **120** to which a first actuating device (e.g., winch) **122** and a second actuating device (e.g., winch) **124** may be attached. The first winch **122** is connected between the body **120** and the second link **114** while the second winch **124** is connected between the body **120** and the first link **108**. Both winches may be activated from the vessels, either to retract or release the corresponding cables and/or ropes. By activating the second winch **124**, a length of the first link **108** is modified, so that the streamer **104** is moved closer or farther along direction X from vessel **103**. By activating the first winch **122**, a length of the second link **114** is modified, so that the streamer **104** is moved laterally (left or right) along direction Y relative to the vessel **103**. When the first winch **122** is activated, the streamer **104** also may move along the X axis. Thus, a control of the streamer **104** is achieved along both the X and Y directions. It is noted that in FIG. **8** the vessel **103** advances along axis X and axis Z indicates a depth at which the streamer **104** is towed relative to a surface of the water. It is also noted the control mechanism **110** may also be used for the exemplary embodiments shown in FIGS. **4-6**.

Winches **122** and **124** do not have to be provided at the control mechanism **110**. For example, the first winch **122** may be provided between the main cable **102** and second link **114**. In another embodiment, only one winch is provided, either the first winch or the second winch. Other arrangements may be employed (e.g., placing second winch **124** on cable **112**) as will be recognized by those skilled in the art as long as control of the streamer **104** is achieved.

FIG. **10** illustrates a side view of the arrangement **100** of FIG. **8**. It is noted that connection **106** is linked by link **130** to a buoy **132** for maintaining the connection **106** at a desired depth under water. Electrical and data cables **134** (lead-in) are attached to the first link **108** and other cables and these data cables **134** are configured to carry electric power and/or data to and from receivers **136** of the streamers **104**. Alternatively, if the second winch **124** is provided on cable **112** as noted above, this cable **112** may become a rope, **108** becomes a lead-in cable and there is no need for cable **134**. A winch **140** may be provided either at buoy **132** or at the connection **106** for adjusting a depth of the connection **106** relative to a surface of the water.

Thus, the catenary front-end gear **100** is capable of individually adjusting a position of the streamer head (connection **106**) on X, Y and Z axes. Other embodiments in which birds are used to control the position of the streamers may be used.

Another arrangement **350** is shown in FIG. **11** in which the catenary tow rope **352**, and the connections **354** and **356** to the streamer **358** are made of the synthetic rope. A lead-in connection **360** is loose. The lead-in connection **360** ensures that data and/or power are transmitted between the vessel and the sensors of the streamers. For the arrangement shown in FIG. **11**, an estimated total drag of **120***t* has been determined, which is similar to a conventional 14×8000×100 streamer arrangement. However, the arrangement **350** has seven more streamers than the conventional streamer arrangement, i.e., it is a 21×8000×100 streamer arrangement. The total drag reduction is evident from this example.

In term of the arrangement of the main cables, the streamer lead-in cables, and the streamers, the previous figures shown only some possible combinations. It is noted that these combinations show the heads of the streamers aligned along a line. However, other configurations for the heads of streamers are possible, e.g., arc of a circle, catenary shape, etc. Other combinations are discussed now with regard to FIG. **12**. FIG. **12** illustrates an exemplary embodiment in which an arrangement **300** has the main catenary tow rope **302** connected to two vessels **304***a* and **304***b*. This arrangement is also applicable to more than two vessels or for a vessel and one or more deflectors. The main cable **302** may be a synthetic cable configured to be strong (e.g., Dyneema fibers, see www-.dyneema.com). The link **304** of the streamer **306** is connected to the catenary tow rope **302** while the data cables **308** and **310** are loosely connected to the link **304** and the catenary tow rope **302**. The data cables **308** and **310** may include cables not only for transmitting data but also for transmitting power, compressed air, gas, etc.

According to an exemplary embodiment illustrated in FIG. **13**, a global position control for the entire gear is discussed. FIG. **13** shows that one or both vessels **103** and **105** have corresponding actuating devices (e.g., winches) **150** and **152** attached to the main cable **102** for changing a length of the main cable **102**. It is noted that FIG. **13** does not show, for simplicity, the actual connection between the streamers **104** and the main cable **102**. FIG. **13** also shows a seismic source **160** towed by the master vessel **103** and another seismic source **162** towed by the slave vessel **105**. Other possible configurations for the seismic sources are possible.

According to another exemplary embodiment, the configuration shown in FIG. **8** may be implemented with a front-end gear configuration that does not use two or more vessels. This arrangement **200** (single vessel tow configuration) is shown in FIG. **14** in which a single vessel **202** tows one or more cables **204**. Cable **204** is connected with the other end to a deflector **206** or another similar device. Thus, the shape of the cable **204** resembles with a catenary arrangement as shown in FIG. **4** or **6**. Streamers **208** are connected to cables **204** in a similar fashion as shown in FIG. **8** (triangular position control system), i.e., each streamer may have a control mechanism **210** that connects to a first link **216**, a lead-in **212** and a second link **214**. The control mechanism **210** may be activated as discussed above with regard to FIG. **9** for controlling the X and Y positions of the streamer **104**. Buoys **132** as shown in FIG. **10** may be used to control the Z position of the streamer **208**.

According to another exemplary embodiment illustrated in FIG. **15**, instead of using the connecting system (**110**, **112**, and **114**) shown in FIG. **9** for positioning a streamer, a bird may be used as shown in the arrangement **250**. This arrangement includes a master vessel **252** connected to deflectors **254** for shaping cables **256** in a catenary way. It is noted that instead of the deflectors **254**, slave vessels as shown in FIG. **4** may be used. Streamers **258** are connected to corresponding birds **260**. Not all streamers have to be connected to a bird. In other ways, it is possible that some streamers are left uncontrolled or the positions of some streamers are controlled by known methods. Thus, the connecting system may include elements **260**, **262** and **264**. This connecting system may also be used for the exemplary embodiments shown in FIGS. **4-6**.

A bird is a device deployed underwater that is capable to change its position based on instructions received from the vessel (e.g., the master vessel) or based on instructions stored at a local control device of the bird (e.g., the bird may have sensors that determine its actual position and a control mechanism adjusts the position of the bird to achieve a desired position). The bird may have wings that are actuated by an appropriate motor for adjusting its position (see U.S. Pat. No. 7,267,070 assigned to the assignee of this application, the entire content of which is incorporated herein by reference).

The bird **260** may be connected to cable **256** via a link **262**. An actuator device **264** (e.g., a winch) may be provided between the cable **256** and link **262** so that a position of the streamer **258** along axis X may be controlled. The bird **260** is configured to move laterally (along axis Y) or up and down (along axis Z) as necessary.

One advantage of one or more of the exemplary embodiments discussed above is that a longitudinal offset (distance between the towing vessels and the heads of the streamers) is reduced. For example, for the exemplary embodiment illustrated in FIG. **8**, such a distance may be less than 200 m, which is substantially less than a corresponding distance for conventional arrangements, which may be around 700 m. In addition, a vertical footprint may be reduced with such a configuration.

According to an exemplary embodiment illustrated in FIG. **16**, there is a method for adjusting a position of a streamer when towed under water. The method includes a step **1600** of towing a main cable (**102**) with at least one vessel (**103**) so that the main cable (**102**) has a catenary shape; a step **1602** of attaching the streamer (**104**) to the main cable (**102**) with a connection and position control system (**112**, **114**, **110**, **108** or **264**, **262**, **260**); and a step **1604** of controlling a position of the streamer (**104**) relative to the at least one vessel.

The disclosed exemplary embodiments provide a system and a method for towing an array of streamers underwater. It should be understood that this description is not intended to limit the invention. On the contrary, the exemplary embodiments are intended to cover alternatives, modifications and equivalents, which are included in the spirit and scope of the invention as defined by the appended claims. Further, in the detailed description of the exemplary embodiments, numerous specific details are set forth in order to provide a comprehensive understanding of the claimed invention. However, one skilled in the art would understand that various embodiments may be practiced without such specific details.

Although the features and elements of the present exemplary embodiments are described in the embodiments in particular combinations, each feature or element can be used alone without the other features and elements of the embodiments or in various combinations with or without other features and elements disclosed herein.

This written description uses examples of the subject matter disclosed to enable any person skilled in the art to practice the same, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the subject matter is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims.

What is claimed is:

1. A catenary front-end gear for towing streamers under water, the catenary front-end gear comprising:

a main cable configured to span between a first vessel and a device;

a connecting system configured to connect plural streamers to the main cable; and

the plural streamers,

wherein the main cable takes a substantially catenary shape when towed by the first vessel underwater and the connecting system is further configured to connect each one of the plural streamers to the main cable at two separate points on the main cable.

2. The catenary front-end gear of claim **1**, wherein the connecting system comprises:

at least one first link configured to be attached to a corresponding streamer;

at least one first lead-in cable configured to attach the at least one first link to the main cable; and

a second link configured to also attach the at least one first link to the main cable.

3. The catenary front-end gear of claim **2**, wherein the device is a deflector.

4. The catenary front-end gear of claim **2**, wherein the device is a second vessel.

5. The catenary front-end gear of claim **2**, further comprising:

a control mechanism configured to connect to (i) the at least one first link, (ii) the at least one first lead-in cable, and (iii) the second link and to control movement of the corresponding streamer in two directions.

6. The catenary front-end gear of claim **5**, wherein the control mechanism comprises:

a first actuator connected between a body of the control mechanism and the second link; and

a second actuator connected between the body and the at least one first link.

7. The catenary front-end gear of claim **1**, further comprising:

a connection provided between the at least one first link and the streamer;

a buoy connected by a cable to the connection and configured to maintain the connection at a predetermined depth under water; and

an actuator between the buoy and the connection and configured to be controlled to adjust the predetermined depth of the connection.

8. The catenary front-end gear of claim **1**, further comprising:

a data cable configured to extend from the streamer or a control mechanism to the first vessel.

9. The catenary front-end gear of claim **1**, wherein the connecting system further comprises:

an actuator connected to the main cable;

a link connected to the actuator;

a bird connected to the link, wherein the bird is configured to laterally and/or vertically change its position; and

a streamer connected to the bird,

wherein the actuator is configured to adjust a longitudinal position of a head of the streamer relative to the first vessel.

10. The catenary front-end gear of claim **9**, wherein the device is a deflector.

11. The catenary front-end gear of claim **9**, wherein the device is a second vessel.

12. A method for adjusting a position of a streamer when towed under water, the method comprising:

towing a main cable with at least one vessel so that the main cable has a catenary shape;

attaching the streamer to the main cable at two separate points on the main cable with a connection and control system; and

controlling a position of the streamer in two directions relative to the at least one vessel using the control system.

13. The method of claim **12**, further comprising:

achieving the catenary shape by spanning the main cable between two vessels or between the at least one vessel and a deflector.

14. A hybrid front-end gear for towing a plurality of streamers underwater along an X axis, the hybrid front-end gear comprising:

a first cable configured to connect to a first vessel and a second vessel;

transversal ropes configured to extend along an Y axis that is substantially perpendicular to the X axis;

a plurality of links configured to connect the transversal ropes to the first cable at a plurality of separate points on the first cable; and a plurality of direct links separate from the plurality of links and configured to connect one or more of the traversal ropes directly to at least one of the first vessel and the second vessel, wherein

the first cable takes a catenary shape when towed underwater, the transversal ropes extend substantially straight along the Y axis and the traversal ropes are configured to connect to the plurality of streamers.

15. The hybrid front-end gear of claim **14**, further comprising:

a second cable configured to connect to the first vessel and a third vessel.

16. The hybrid front-end gear of claim **15**, wherein:

the plurality of links are further configured to connect the transversal ropes to the second cable at a plurality of separate points on the second cable; and

the plurality of direct links connect one or more of the transversal ropes directly to the first vessel, the second vessel and the third vessel.

17. The hybrid front-end gear of claim **14**, further comprising:

plural streamers connected between the transversal ropes; and

a connecting system for connecting the plural streamers to the transversal ropes,

wherein the connecting system includes actuators and/or birds.

18. The hybrid front-end gear of claim **14**, further comprising:

at least one first link configured to be attached to a corresponding streamer;

at least one lead-in cable configured to attach the at least one first link to the main cable; and

a second link configured to also attach the at least one first link to the first cable.

19. The hybrid front-end gear of claim **18**, further comprising:

a control mechanism configured to connect to (i) the at least one first link, (ii) the at least one lead-in cable, and (iii) the second link, wherein the control mechanism comprises,

a first actuator connected between a body of the control mechanism and the second link; and

a second actuator connected between the body and the at least one first link.

20. The hybrid front-end gear of claim **14**, further comprising:

a connection provided between the at least one first link and the streamer;

a buoy connected by a cable to the connection and configured to maintain the connection at a predetermined depth under water; and

an actuator between the buoy and the connection and configured to be controlled to adjust the predetermined depth of the connection.

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